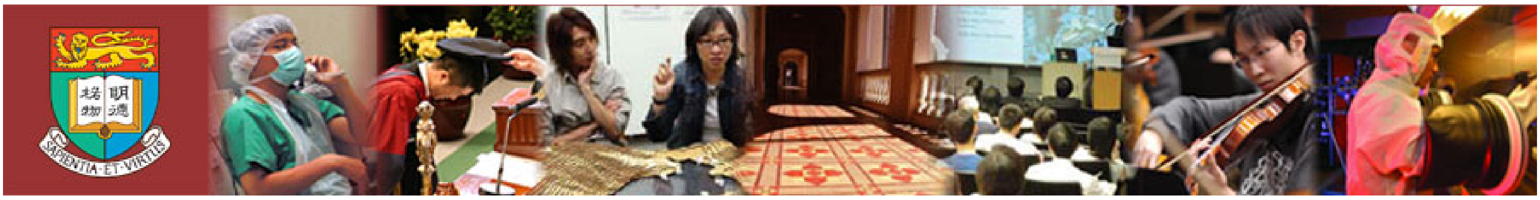

Title	A dual-band bandpass filter using a single dual-mode ring resonator
Author(s)	Sun, S
Citation	IEEE Microwave and Wireless Components Letters, 2011, v. 21 n. 6, p. 298-300
Issued Date	2011
URL	http://hdl.handle.net/10722/139262
Rights	©2011 IEEE. Personal use of this material is permitted. However, permission to reprint/republish this material for advertising or promotional purposes or for creating new collective works for resale or redistribution to servers or lists, or to reuse any copyrighted component of this work in other works must be obtained from the IEEE.

A Dual-Band Bandpass Filter Using a Single Dual-Mode Ring Resonator

Sheng Sun, *Member, IEEE*

***Abstract*—A simple microstrip ring-resonator is presented for novel design of dual-band dual-mode bandpass filters with good isolation and upper-stopband performance. By increasing the length of the loaded open-circuited stub, the two first-order degenerate modes are excited and slit for the use of the first passband, while one of the third-order degenerate modes moves downward and forms the second passband together with a second-order degenerate mode. Meanwhile, three transmission zeros are properly tuned for the rejections between the two passbands and in the upper stopband. After installing two coupled-line sections on a square ring at the two ports with 90°-separation, a dual-band filter with the two transmission poles in each passband is designed and measured. Without adding any additional perturbation element inside the ring, the measured filter shows good performance for both in-band matching and outside rejections of the desired dual passbands.**

***Index Terms*—Bandpass filter (BPF), dual-mode dual-band, isolation, ring resonator, transmission zeros.**

I. Introduction

MICROSTRIP ring resonators have been widely used for applications in planar circuits, such as filters, antennas and other microwave components [1]. Because of the coexisting of the two degenerate orthogonal modes, a ring resonator owns the advantages of compact size and high-quality (Q) factor. For the dual-band applications using the dual-mode ring resonator, one of the most important issues is how to excite two degenerate modes and generate two transmission poles with a single resonator in each passband [2]. By using the stepped-impedance topology with a variable impedance ratio, the resonant frequencies of the ring resonator become adjustable [3]. However, only a single transmission pole was created in the second passband because of the symmetrical topology at the second-order resonance. To overcome this issue, two dissimilar ring resonators with different first-order resonant frequencies were directly combined together to achieve the desired dual-passband performance [4], [5]. Depositing the increasing size, a complex feeding structure was usually required to be installed at the different layers [6], [7].

Recently, a class of dual-mode dual-band bandpass filters (BPFs) based on a single ring resonator were designed in [2], [8]. Instead of a common two-port excitation angle, i.e., either 90° or 180°, the two excitation ports were placed at 45° or 135°-separation. In [2], the two pairs of the first- and second-order degenerate modes of the ring resonator were excited and utilized to form two passbands individually, while the first- and third-order degenerate modes could also be utilized by installing two additional impedance transformers [8]. A class of dual-mode dual-band ring resonator BPFs using microwave C-sections was recently reported in [9], where the first- and second-order degenerate modes could also be excited by selecting the excitation angle as 60°. Nevertheless, these structures also need many perturbation elements to be installed along the ring.

In this letter, two coupled-line sections are simply installed on a single ring resonator at the two ports with 90°-separation. We could see that the two first-order degenerate modes are excited to form the first passband with two transmission poles, while the second passband is also constructed with two poles. In this case, the second-order degenerate modes cannot be disturbed and split with orthogonal feeding [2], [3]. Fortunately, one of the third-order degenerate modes can be dropped down by attaching the coupled-line section and utilized to produce another transmission pole at the second passband. As shown in Fig. 1, the two transmission poles can be easily generated in each passband by selecting the suitable length (L_s) of the attached line section. With the help of the coupled-line section, three transmission zeros will also be produced and controlled to provide a good isolation and wide upper stopband. A dual-band filter is then designed and measured to demonstrate the good in-band matching and the good rejections outside the desired dual passbands.

II. Ring Resonators With Coupled Lines

Fig. 1 shows the schematic and its equivalent even- and odd-mode resonant circuits for the proposed dual-band ring resonator BPF. It consists of a single resonator and two identified coupled-line sections. Based on the even-odd mode analysis under the weak coupling [2], the symmetrical plane in Fig. 1(a) becomes the perfect magnetic wall and electric wall, respectively. Y_l and $Y_r^{e,o}$ represent the two input admittances at two ports, looking into the left and right sides of the one-port bisection network, which is a one-port network with open- and short-circuited ends in the plane of symmetry accordingly, as show in Fig. 1(b) and 1(c). Y_s and θ_s are the characteristic admittance and the electrical length of the loaded open-circuited stub on the ring. According to the transverse resonance

Manuscript received November 25, 2010; revised February 24, 2011; accepted March 16, 2011. Date of publication May 12, 2011; date of current version June 02, 2011. This work was supported in part by the Alexander von Humboldt Foundation, Germany.

The author is with the Department of Electrical and Electronic Engineering, The University of Hong Kong, Hong Kong, China (e-mail: sunsheng@ ieee. org).

Color versions of one or more of the figures in this letter are available online at http://ieeexplore.ieee.org.

Digital Object Identifier 10.1109/LMWC.2011.2132119

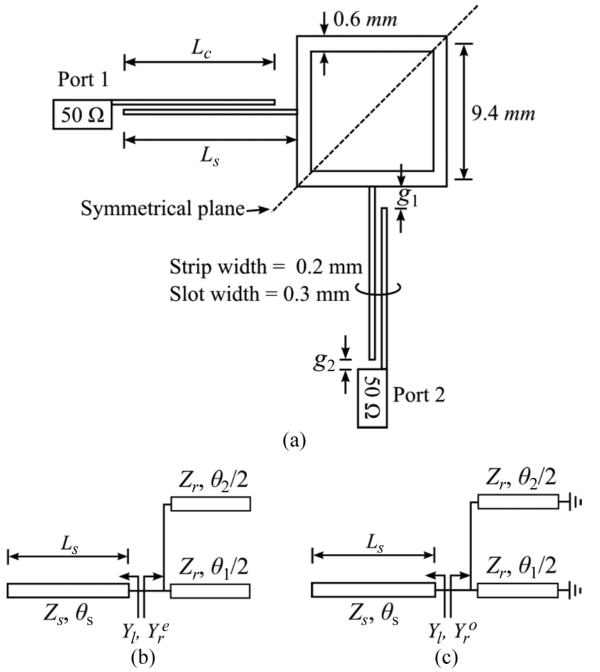

Fig. 1. (a) Schematic of the proposed dual-band ring-resonator BPF with varied stub length (L_s) and gap distances (g_1 and g_2). (b) Equivalent even-mode circuit of the resonator. (c) Equivalent odd-mode circuit of the resonator.

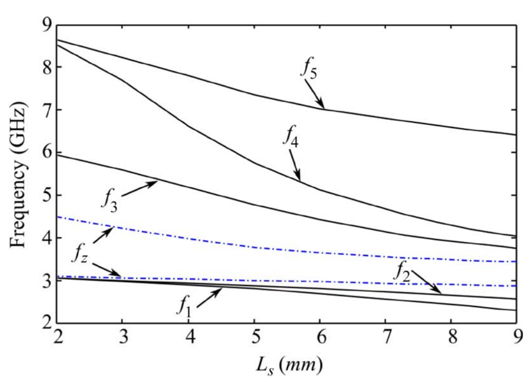

Fig. 2. Frequencies of the transmission poles (solid lines) and zeros (blue dotted-broken lines) with varied transmission line length (L_s).

technique, all the resonant frequencies under the even- and odd-mode excitation satisfy [2]

$$\mathrm{Im}\left(Y_l + Y_r^e\right) = 0 \tag{1}$$
$$\mathrm{Im}\left(Y_l + Y_r^o\right) = 0 \tag{2}$$

where

$$Y_l = jY_s \tan\theta_s \tag{3}$$
$$Y_r^e = \mathrm{j}Y_r\left(\tan\frac{\theta_1}{2} + \tan\frac{\theta_2}{2}\right) \tag{4}$$
$$Y_r^o = -\,\mathrm{j}Y_r\left(\cot\frac{\theta_1}{2} + \cot\frac{\theta_2}{2}\right). \tag{5}$$

Due to the transversal interference between the two signal paths from one port to the other port, as discussed in [10], the transmission zeros in this case $(\theta_2 = 3\theta_1)$ appear at

$$\theta_1 = 2(n+1)\times 90^\circ, \quad n = 0, 1, 2, \ldots \tag{6}$$

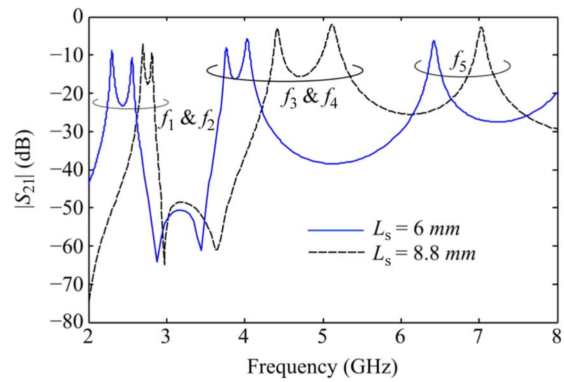

Fig. 3. Frequency responses of the ring resonator under the weak coupling with different line length (L_s).

However, the line dispersion and the parasitic effects of discontinuities also impact the exact locations of the frequencies of these transmission poles and zeros. Fig. 2 plots the five transmission pole frequencies (f_i, $i =$ 1, 2, 3, 4, & 5) and two transmission zero frequencies (f_z) versus the line length (L_s), as shown in Fig. 1(a). It can be seen that all the transmission pole frequencies become smaller as L_s increases. Note that the first two resonances at f_1 and f_2, coalesce initially and split from each other as L_s increases from 2 to 9 mm. It implies that the first-order degenerate modes are slit and the two transmission poles in the first desired passband around 2.3 GHz become possible as L_s extends. The fourth resonance, f_4, shifts down quickly and builds up the second passband together with the third resonance (f_3) around 4.0 GHz. Fig. 3 shows the frequency responses of the proposed ring resonator under a weak coupling. While the line length L_s increases from 6 to 8.8 mm, the third and fourth resonances (f_3 and f_4) further move close to each other and thus form a second passband, which has a similar bandwidth and quasi-symmetrical responses as the first passband. In particular, the fifth resonance (f_5) becomes the first harmonic frequency of this dual-band filter, which is very close to the transmission zero frequency of the coupled-line section [11]. By slightly adjusting the two gap distances (g_1 and g_2) as shown in Fig. 1(a), this additional transmission zero can be varied and utilized to suppress the harmonic frequency at f_5. Different from the work in [2], [8], [9], the second passband in this work is constructed by a second-order degenerate mode at f_3 and one of the third-order degenerate modes at f_4. In addition, two transmission zeros are always located between two desired passbands, thus providing a good isolation. On the other hand, one of the open-ends of the coupled-line section, as shown in Fig. 1(a), is arranged close to the ring resonator with a small gap (g_1), which can be considered as an additional perturbation to the transversal interference between two signal paths [10]. Hence, the distance between zeros can be adjusted, as shown in Fig. 4. As g_1 is increased from 0.1, 0.6 to 1.0 mm, the rejection level increases from 32, 40 to 44 dB due to the shrunken distance between zeros.

III. Experimental Results

To provide verification on the above proposed structure, a prototype filter circuit is designed and optimized with dual passbands at 2.3 and 4.1 GHz in a full-wave electromagnetic

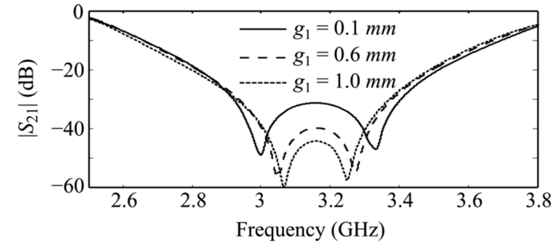

Fig. 4. Frequency responses with varied gap distance (g_1) when $L_s = 9\ \mathrm{mm}$.

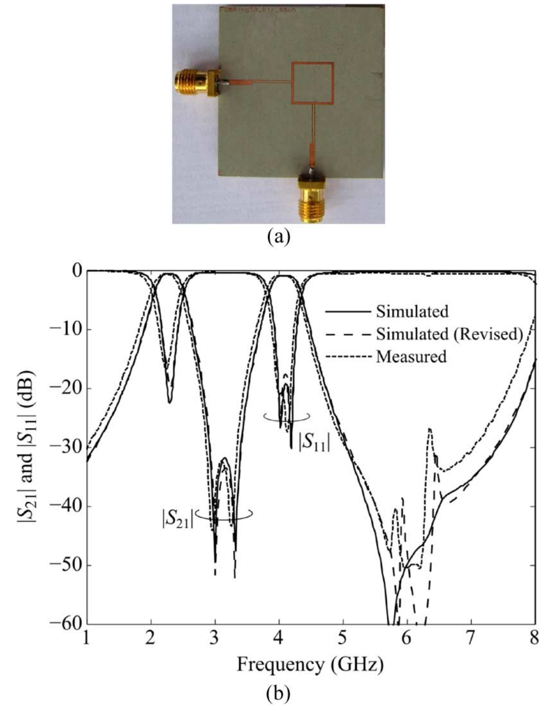

Fig. 5. Photograph, simulated and measured results of the proposed simple dual-band ring-resonator BPF. (a) Photograph of the fabricated circuit. Dimensions: $L_s = 9.0\ \mathrm{mm}$, $g_1 = g_2 = 0.1\ \mathrm{mm}$, $L_c = 8.9\ \mathrm{mm}$. Substrate: RT/Duroid 6010 with $h = 1.27\ \mathrm{mm}$ and $\varepsilon_r = 10.8$. (b) Simulated, revised, and measured results.

simulator [12]. Fig. 5(a) shows the photograph of the fabricated circuit. Fig. 5(b) shows its frequency responses over a wide frequency range from 1.0 to 8.0 GHz. A good agreement is achieved between the simulated and the measured results. The measured minimum insertion loss achieves 0.65 dB in the first passband and 1.0 dB in the second passband. As predicted, two transmission zeros are observed at 2.96 and 3.26 GHz, respectively, which also results in a 32 dB isolation from 2.88 to 3.34 GHz. With the help of an additional transmission zero provided by the coupled-line section [11], the harmonic brought by the fifth resonance (f_5) can be fully suppressed as shown in the simulated results. However, two unexpected peaks are raised at 5.83 and 6.35 GHz, respectively. After measuring the real dimensions of the fabricated circuits, we found that these unmatched responses are due to the fabrication tolerance. As shown with the dash-line in Fig. 5(b), the re-simulated results are much close to the measured results. In the measured upper-stopband responses, a 26 dB rejection in the frequency range of 4.87 to 7.30 GHz is also obtained.

IV. Conclusion

In this letter, a dual-band BPF using a single microstrip ring resonator has been presented. The two transmission poles are generated in each passband after installing two coupled-line sections at two excitation ports. With a common two-port excitation angle of 90°, two transmission zeros are placed between the two passbands and resulted in a good isolation. The harmonic frequency caused by the fifth resonance of the resonator has also been suppressed by an additional zero brought by the coupled-line section, thus widening the upper stopband. For the pre-specified passbands, the dual operating frequencies can be appropriately tuned by forming a nonuniform ring resonator with periodically-loaded stubs or stepped-impedance configuration as discussed in [3] and [8].

Acknowledgment

The author would like to thank Dr. W. Menzel and his research team at the University of Ulm, Germany, for their great support in this research.

References

[1] K. Chang and L. H. Hsieh, *Microstrip Ring Circuits and Related Structures*. New York: Wiley, 2004.
[2] S. Luo, L. Zhu, and S. Sun, “A dual-band ring-resonator bandpass filter based on two pairs of degenerate modes,” *IEEE Trans. Microw. Theory Tech.*, vol. 58, no. 12, pp. 3427–3432, Dec. 2010.
[3] T.-H. Huang, H.-J. Chen, C.-S. Chang, L.-S. Chen, Y.-H. Wang, and M.-P. Houng, “A novel compact ring dual-mode filter with adjustable second-passband for dual-band applications,” *IEEE Microw. Wireless Compon. Lett.*, vol. 16, no. 6, pp. 360–362, Jun. 2006.
[4] J.-X. Chen, T. Y. Yum, J.-L. Li, and Q. Xue, “Dual-mode dual-band bandpass filter using stacked-loop structure,” *IEEE Microw. Wireless Compon. Lett.*, vol. 16, no. 9, pp. 502–504, Sep. 2006.
[5] X. Y. Zhang and Q. Xue, “Novel dual-mode dual-band filters using coplanar-waveguide-fed ring resonators,” *IEEE Trans. Microw. Theory Tech.*, vol. 55, no. 10, pp. 2183–2190, Oct. 2007.
[6] E. E. Djoumessi and K. Wu, “Multilayer dual-mode dual-bandpass filter,” *IEEE Microw. Wireless Compon. Lett.*, vol. 19, no. 1, pp. 21–23, Jan. 2009.
[7] J.-W. Baik, L. Zhu, and Y.-S. Kim, “Dual-mode dual-band bandpass filter using balun structure for single substrate configuration,” *IEEE Microw. Wireless Compon. Lett.*, vol. 20, no. 11, pp. 613–615, Nov. 2010.
[8] S. Luo and L. Zhu, “A novel dual-mode dual-band bandpass filter based on a single ring resonator,” *IEEE Microw. Wireless Compon. Lett.*, vol. 19, no. 8, pp. 497–499, Aug. 2009.
[9] Y.-C. Chiou, C.-Y. Wu, and J.-T. Kuo, “New miniaturized dual-mode dual-band ring resonator bandpass filter with microwave C-sections,” *IEEE Microw. Wireless Compon. Lett*, vol. 20, no. 2, pp. 67–69, Feb. 2010.
[10] R. Gomez-Garcia, M. Sanchez-Renedo, B. Jarry, J. Lintignat, and B. Barelaud, “A class of microwave transversal signal interference dual-passband planar filters,” *IEEE Microw. Wireless Compon. Lett*, vol. 19, no. 3, pp. 158–160, Mar. 2009.
[11] S. Sun and L. Zhu, “Wideband microstrip ring resonator bandpass filters under multiple resonances,” *IEEE Trans. Microw. Theory Tech.*, vol. 55, no. 10, pp. 2176–2182, Oct. 2007.
[12] *“Advanced Design System (ADS) 2009,”* Agilent Technologies, 2009.